

FORM PTO-1390		U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER 1587.GLE.PT
<b>TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/ES/US) CONCERNING A FILING UNDER 35 U.S.C 371</b>			U.S. APPLICATION NO (If known, see 37 CFR 1.5) <b>09/787045</b>
INTERNATIONAL APPLICATION NO PCT/EP99/06800	INTERNATIONAL FILING DATE 14 September 1999	PRIORITY DATE CLAIMED 16 September 1998	
TITLE OF INVENTION PROCESS AND APPARATUS FOR THE PRODUCTION OF WEAR-RESISTANT SURFACES			
APPLICANT(S) FOR DO/EO/US Christof Lausser, Hans-Jürgen Lauth			
<p>Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:</p> <ol style="list-style-type: none"> <li><input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li><input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li><input type="checkbox"/> This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).</li> <li><input checked="" type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19<sup>th</sup> month from the earliest claimed priority date.</li> <li><input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))             <ol style="list-style-type: none"> <li><input checked="" type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau).</li> <li><input type="checkbox"/> has been transmitted by the International Bureau.</li> <li><input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</li> </ol> </li> <li><input checked="" type="checkbox"/> A translation of the International Application into English (35 U.S.C. 371(c)(2)).</li> <li><input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).             <ol style="list-style-type: none"> <li><input checked="" type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau).</li> <li><input type="checkbox"/> have been transmitted by the International Bureau.</li> <li><input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</li> <li><input type="checkbox"/> have not been made and will not be made.</li> </ol> </li> <li><input checked="" type="checkbox"/> A translation of the amendments to the claims under PCT Article 10 (35 U.S.C. 371(c)(3)).</li> <li><input type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).</li> <li><input checked="" type="checkbox"/> A translation of the annexes to the International Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</li> </ol> <p><b>Items 11. to 16. below concern document(s) or information included:</b></p> <ol style="list-style-type: none"> <li><input checked="" type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</li> <li><input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</li> <li><input checked="" type="checkbox"/> A <b>FIRST</b> preliminary amendment.             <ul style="list-style-type: none"> <li><input type="checkbox"/> A <b>SECOND</b> or <b>SUBSEQUENT</b> preliminary amendment.</li> </ul> </li> <li><input type="checkbox"/> A substitute specification.</li> <li><input type="checkbox"/> A change of power of attorney and/or address letter.</li> <li><input checked="" type="checkbox"/> Other items or information:             <ul style="list-style-type: none"> <li>- Certificate of Mailing</li> <li>- Postcard</li> </ul> </li> </ol>			

U.S. APPLICATION NO (if known, see 37 CFR 1.51) <div style="font-size: 24pt; font-weight: bold; margin-top: 5px;">09/787045</div>	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER			
17. <input type="checkbox"/> The following fees are submitted: <b>BASIC NATIONAL FEE (37 CFR 1.492 (a)(1) - (5)):</b> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO . . . . . <b>\$970.00</b>  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO. . . . . <b>\$840.00</b>  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO . . . . . <b>\$690.00</b>  International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4). . . . . <b>\$670.00</b>  International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4). . . . . <b>\$96.00</b> <div style="text-align: center; font-weight: bold;">ENTER APPROPRIATE BASIC FEE AMOUNT -</div>		<div style="border: 1px solid black; padding: 5px;"> <b>CALCULATIONS</b> <span style="float: right;">PTO USE ONLY</span> </div>			
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input checked="" type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).		<div style="border: 1px solid black; padding: 5px;">         840.00       </div>			
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	-20 =		X \$18.00	\$	
Independent claims	-3 =		X \$78.00	\$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$260 00	\$	
TOTAL OF ABOVE CALCULATIONS =				\$970.00	
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28).				\$	
SUBTOTAL =				\$	
Processing fee of <b>\$130.00</b> for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
TOTAL NATIONAL FEE =				\$	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). <b>\$40.00</b> per property +				\$	
TOTAL FEES ENCLOSED =				\$970.00	
				Amount to be refunded:	\$
				charged:	\$

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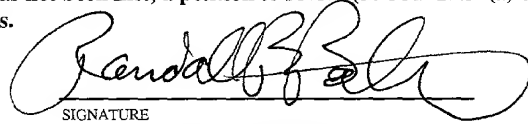
JC08 Rec'd PCT/PTO 13 MAR 2001

- a. ☒ A credit card authorization in the amount of \$970.00 to cover the above fees is enclosed.
- b. ☐ Please charge my Deposit Account No. 50-0881 in the amount of \$\_\_\_\_\_ to cover the above fees.  
A duplicate copy of this sheet is enclosed.
- c. ☒ The Commissioner is hereby authorized to charge additional fees which may be required, or credit any overpayment to Deposit Account No. 50-0881. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO

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SIGNATURE

Randall B. Bateman

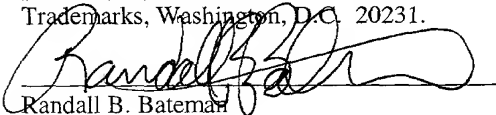
NAME

37,774

REGISTRATION NUMBER

CERTIFICATE OF DEPOSIT UNDER 37 C.F.R. § 1.10

I hereby certify that this correspondence is being deposited with the United States Postal Service as First Class Mail, postage prepaid, under 37 C.F.R. § 1.10 on the date indicated below and is addressed to Asst. Commissioner for Patents & Trademarks, Washington, D.C. 20231.



Randall B. Bateman

3/13/01  
Date

EXPRESS MAIL NO. EL 593621467 US

09/787045

JG08 Rec'd PCT/PTO 13 MAR 2001

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Christof Lausser et al.

U.S. Serial Number: \_\_\_\_\_

PCT App. No. PCT/EP99/06800  
(Claiming Priority to: German Patent App. No. 19842284.9)

Filed: September 14, 1999

Group: \_\_\_\_\_

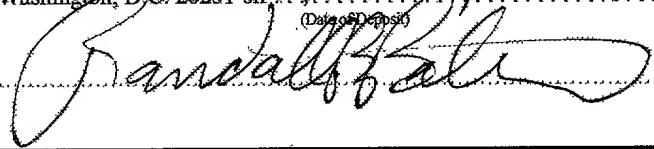
Examiner: \_\_\_\_\_

For: PROCESS AND APPARATUS FOR THE PRODUCTION OF  
WEAR-RESISTANT SURFACES

Attorney Docket: 1587.GLE.PT

Assistant Commissioner of Patents  
and Trademarks  
Washington, D. C. 20231

I hereby certify that this correspondence is being deposited with the United  
States Postal Service via Express Mail addressed to:  
Assistant Commissioner of Patents and Trademarks,  
Box PCT  
Washington, D.C. 20231 on Mar. 13, 2001  
(Date of Deposit)



PRELIMINARY AMENDMENT

Dear Sir:

Prior to calculation of fees and examination of the above-referenced patent application, please  
make the following amendments to the application:

IN THE SPECIFICATION:

Please replace pages 1 through 5 with replacement sheets 1 through 5 attached hereto.

IN THE DRAWINGS:

Please amend FIGs. 2A through 2C as indicated.

IN THE CLAIMS:

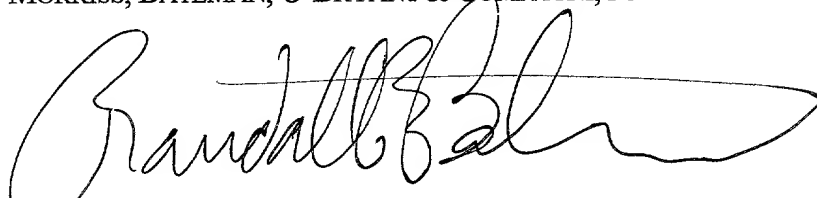
Please cancel claims 1 through 9 and add new claims 10 through 24 as presented in the enclosed replacement pages.

**REMARKS**

Applicant has amended the application to conform to U.S. Practice and respectfully submits that the pending claims are believed to be in condition for allowance. Should the Examiner determine that any adverse action is necessary, it is respectfully requested that he contact Applicant's attorney, Randall B. Bateman at (801) 685-2302 so that such matters may be resolved as expeditiously as possible. The Director is hereby authorized to credit any overpayment or charge any amount owing regarding this case to Account No. 50-0881.

Respectfully Submitted,

MORRISS, BATEMAN, O'BRYANT & COMPAGNI, PC



Randall B. Bateman  
Reg. No. 37,774

## Process for the Production of Wear-resistant Surfaces

### Background

The invention relates to a process for the production of wear-resistant, coated surfaces.

Processes of the type addressed here are known. They serve for example to provide a surface consisting of aluminum or an aluminum alloy, for example the surface of a hole, with an oxide layer. To carry out the prior-art coating process the workpiece is connected to the positive pole of a voltage source, therefore forming the anode. A lead plate connected to the negative pole forms the cathode which is introduced into the hole. An electrolyte, here diluted sulfuric acid, is conducted into the chamber bordered by the workpiece and the cathode. The chamber has an inlet and an outlet and the electrolyte flows through in one direction. It has been proven disadvantageous that the thickness of the aluminum oxide layer is different over the surface to be coated, that is, on one side of the workpiece the thickness of the oxide layer is greater than on the other side. Thereby desired tolerances in the form of the surface can be adhered to in all cases so that the coated surface must be reworked, for example, by grinding or honing in order to achieve a high precision in form and dimensions.

DE 1 909 870 describes a process for the galvanic deposition of metals on the outer and inner surfaces of porous metallic, or premetallized non-metallic, formed bodies. It was discovered that on the outer as well as on the inner metallic surfaces of a porous formed body a nearly uniform galvanic deposition of metal can be achieved if the electrolyte is pressed through the pores of the formed body serving as electrode at a certain rate, preferably at a rate of 80 to 130 cm/sec. If the

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formed body is very thick-walled, then a reduction of the layer thickness of the metal deposit in the direction of flow of the electrolyte is observed. By timed reversal of the direction of flow of the electrolytes and by arrangement of two anodes this disadvantage can be eliminated.

### Summary and Object of the Invention

It is the objective of the invention to provide a process of the type stated initially which does not have the disadvantages described initially.

For the realization of the objective of the invention a process with the features of claim 1 is proposed. This is distinguished by the fact that the direction of flow of the electrolyte during the coating process is reversed at least once. By the reversal of the direction of flow of the electrolyte at a preferably precisely defined point in time a specific effect on the distribution of the thickness of the layer and the desired theoretical dimensions is possible, that is, the thickness of the wear-resistant layer generated by the electrolyte can be adjusted. Thereby the form of the surface to be coated, therefore, for example, the conicity of a hole or the planeness of a plate can be influenced.

The surface to be coated consists of aluminum or an aluminum alloy. An oxide layer is formed thereon which is also designated as anodizing layer. This form of electrolysis is also designated as anodizing or anodic oxidation in which the workpiece to be coated serves as anode and a, for example lead, plate serves as cathode, both being introduced into a reaction space or bordering it. An electrolyte, for example diluted sulfuric acid, flows through the reaction space. The anodizing

layer generated by the anodizing is hard and very resistant to the influence of chemicals.

In an advantageous form of embodiment of the process the surface to be coated is curved, in particular cylindrical, or plane. By the deliberate reversal of the direction of flow of the electrolyte the form and/or the theoretical dimension can therefore be influenced in the case of curved as well as plane surfaces. The process according to the invention is particularly advantageous in the coating of a passageway or a sack hole on whose precision of form and dimension high demands are made, such as, for example, a hole for a valve piston of a conveyance device used in a vehicle. In many cases a hole has a conical form instead of a cylindrical one after its completion, which can be compensated or eliminated by the deliberate reversal of the direction of flow of the electrolyte during the coating of the surface. Furthermore, the form of plane surfaces can be intentionally changed, in particular adjusted, with the aid of the above-described process by influencing the distribution of the thickness of the layer. Thereby plane surfaces can be produced which have a high precision of dimension.

An apparatus for carrying out the process includes a reaction space connected to at least two connecting lines of which a first connecting line serves as inlet and a second connecting line serves as outlet for an electrolyte which can be transported by means of a feed line. The workpiece to be coated or the at least one surface is introduced into the reaction space and at least brought into contact with the electrolyte. It is also possible that the workpiece borders or forms a part of the reaction space. This is, for example, possible in the case of a workpiece with a hole to be coated. An electrode is introduced into the hole whose surface is intended to be coated. At least one



anode is located in the reaction space and a cathode or the workpiece is connected to one of the two poles of the voltage source and thus forms the anode or the cathode. The apparatus is distinguished by the fact that in the path of flow of the electrolyte a change-over device, for example, a valve, is provided with whose aid the inlet and the outlet can be interchanged. With the aid of the manually or automatically switchable change-over device a reversal of the direction of flow of the electrolyte through the reaction space at a definite point in time is possible so that a constant layer thickness or different layer thickness can be realized on the surface to be coated. Thereby the form of the surface, for example that of the hole, plate, or the like can be influenced. The inlet and the outlet are in the case of a preferred exemplary embodiment connected to the reaction space at a distance from one another in such a manner that the electrolyte preferably flows by on the entire, at least however on a large part, of the surface to be coated.

Additional advantageous forms of embodiment follow from the remaining subordinate claims.

#### Brief Description of the Drawings

The invention will be explained in more detail in the following with the aid of the drawings.

FIG. 1 shows a schematic view of one exemplary embodiment of an apparatus of the present invention, for use in oxidizing a working surface is oxidized in accordance with the principles of the present invention;

FIG. 2A shows a cross-sectional view of a hole being coated in accordance with the principles of the present invention;

FIG. 2B shows a cross-sectional view of a hole being coated in accordance with the principles of the present invention;

FIG. 2C shows a cross-sectional view of a hole being coated in accordance with the principles of the present invention;

FIG. 3A shows a perspective view of an additional exemplary embodiment of the apparatus in accordance with the present invention; and

FIG. 3B shows a view similar to that of FIG. 3A with the flow reversed.

Figure 1 shows a schematic sketch of a first exemplary embodiment of an apparatus 1 for the production of wear-resistant, coated surfaces, here of a cylindrical, or essentially cylindrical, sack hole

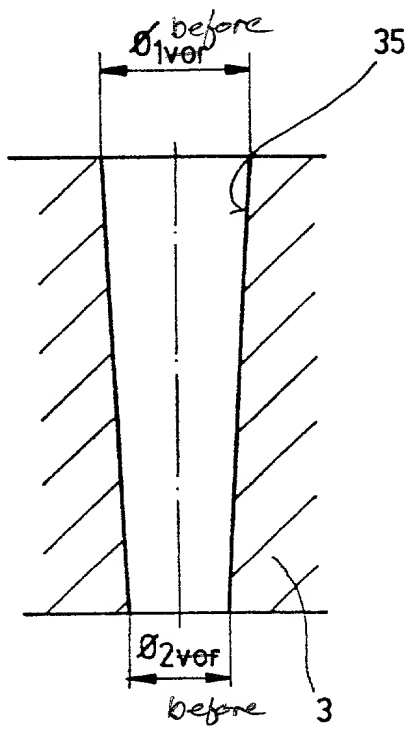


Fig. 2A  
*Amended*

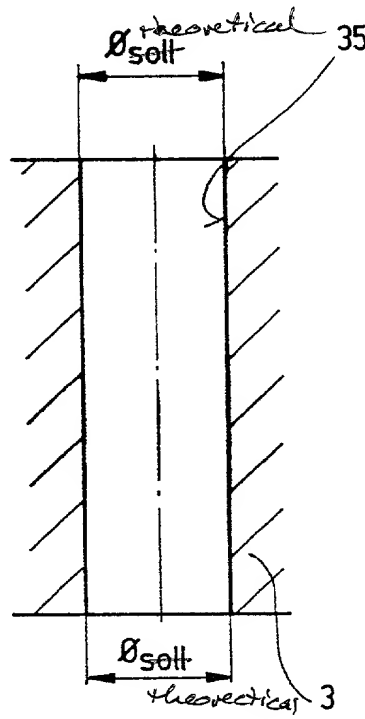


Fig. 2B  
*Amended*

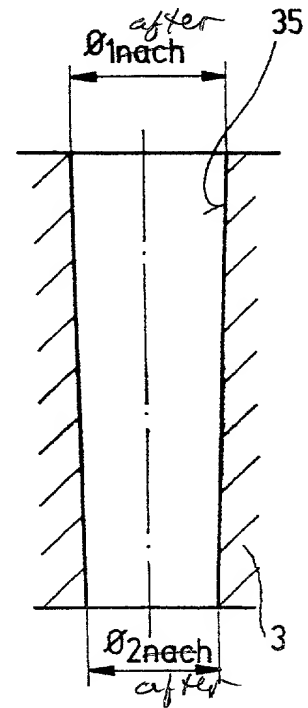


Fig. 2C  
*Amended*

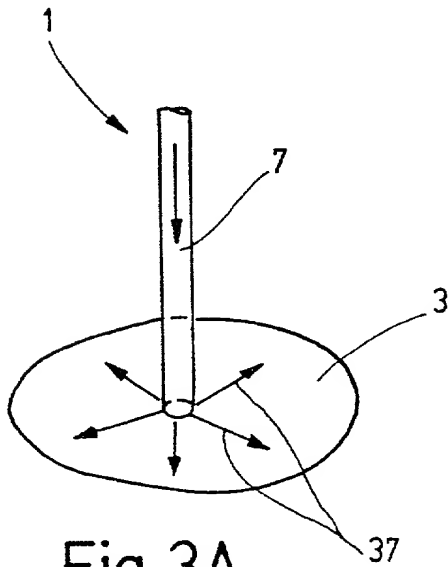


Fig. 3A

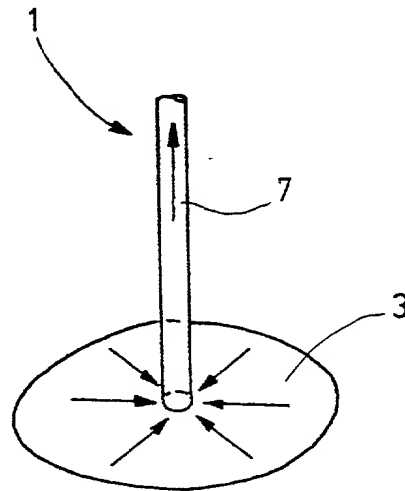


Fig. 3B

## CLAIMS

What is claimed is:

10. (New) A process for the production of wear-resistant, coated surfaces with at least two electrodes connected to a voltage source which are disposed adjacent a reaction space through which an electrolyte flows in which the surface to be coated is located, the process comprising:

selectively reversing flow of the electrolyte at least once during the coating process for an amount of time as a function of the form of the surface of the workpiece before or during the coating process; and

thereby forming an oxide layer ( $\text{Al}_2\text{O}_3$ ) on a surface selected from the group consisting of aluminum and an aluminum alloy.

11. (New) The process according to claim 1, wherein the method comprises reversing flow based on precalculated flow times.

12. (New) The process according to claim 1, wherein the electrolyte flows in a certain direction is determined as a function of the form of the surface of the workpiece before the coating process.

13. (New) The process according to claim 10, wherein the method comprises coating a surface which is curved.

14. (New) The process according to claim 10, wherein the method comprises coating a

surface which is plane.

15. (New) The process according to claim 10, wherein the method comprises selectively reversing flow to develop different layer thicknesses on the surface to be coated.

16. (New) The process according to claim 10, wherein the method comprises selecting a workpiece having a frusto-conical void formed therein and selectively reversing the flow of electrolyte to form an oxide layer defining a generally cylindrical void.

17. (New) The process according to claim 10, wherein the method comprises disposing at least two connecting lines in communication with the working surface, where a first connecting line serves as the inlet and a second connecting line serves as the outlet for the electrolyte which can be transported with the aid of a feed line and at least two electrodes connected to a voltage source which are disposed in communication with the reaction space, and a change-over device for selectively reversing flow through the inlet and the outlet.

18. (New) The process according to claim 10 wherein the method comprises forming one electrode from the surface to be coated.

19. (New) A workpiece having defining a valve hole with a surface which is generally conical and an oxide coating with a distribution of layer thicknesses so that the coated surface has a cylindrical form.

20. (New) An apparatus for the production of wear-resistant surfaces with a reaction space comprising to at least two connecting lines where a first connecting line serves as the inlet and a second connecting line serves as the outlet for an electrolyte which can be transported with the aid of a feed line and at least two electrodes connected to a voltage source which are disposed in communication with the reaction space, and a change-over device for selectively reversing flow through the inlet and the outlet.

21. (New) The apparatus according to claim 20 wherein at least one electrode is formed from a working surface to be coated, the working surface being selected from the group consisting of aluminum and an aluminum alloy.

22. (New) The apparatus according to claim 20, wherein the working surface is curved.

23. (New) The apparatus according to claim 22, wherein the working surface is cylindrical.

24. (New) The apparatus according to claim 23, wherein the working surface defines a plane.

## ABSTRACT

A process for the production of wear-resistant, coated surfaces includes the use of at least two electrodes connected to a voltages source which are mounted in, or border, a reaction space through which an electrolyte flows in which the surface to be coated is located. The process is distinguished by the fact that the direction of the flow of the electrolyte is selectively reversed at least once during the coating process to enable better control of the formation of the oxide layer.

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- 1 -

Process and Apparatus for the Production of Wear-resistant Surfaces

Description

The invention relates to a process for the production of wear-resistant, coated surfaces according to the preamble of claim 1 as well as an apparatus for the production of wear-resistant surfaces according to the preamble of claim 6.

Processes and apparatuses of the type addressed here are known. They serve for example to provide a surface consisting of aluminum or an aluminum alloy, for example the surface of a hole, with an oxide layer. To carry out the prior-art coating process the workpiece is connected to the positive pole of a voltage source, therefore forming the anode. A lead plate connected to the negative pole forms the cathode which is introduced into the hole. An electrolyte, here diluted sulfuric acid, is conducted into the chamber bordered by the workpiece and the cathode. The chamber has an inlet and an outlet and the electrolyte flows through in one direction. It has been shown disadvantageous that the thickness of the aluminum oxide layer is different over the surface to be coated, that is, on one side of the workpiece the thickness of the oxide layer is greater than on the other side. Thereby, desired tolerances in the form of the surface can be adhered to in all cases so that the coated surface must be reworked, for example, by grinding or honing in order to achieve a high precision in form and dimensions.

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It is thus the objective of the invention to provide a process and an apparatus of the type stated initially which does not have these disadvantages.

For the realization of the objective of the invention a process with the features of claim 1 is proposed. This is distinguished by the fact that the direction of flow of the electrolyte during the coating process is reversed at least once. By the reversal of the direction of flow of the electrolyte at a preferably precisely defined point in time a specific effect on the distribution of the thickness of the layer and the desired theoretical dimensions is possible, that is, the thickness of the wear-resistant layer generated by the electrolyte can be adjusted. Thereby the form of the surface to be coated, therefore, for example, the conicity of a hole or the planeness of a plate can be influenced.

Particularly preferred is a form of embodiment of the process in which at least the surface to be coated consists of aluminum or an aluminum alloy and that an oxide layer is formed thereon which is also designated as anodizing layer. This form of electrolysis is also designated as anodizing or anodic oxidation in which the workpiece to be coated serves as anode and a, for example lead, plate serves as cathode, both being introduced into a reaction space or bordering it. An electrolyte, for example diluted sulfuric acid, flows through the reaction space. The anodizing layer generated by the anodizing is hard and very resistant to the influence of chemicals.

In an advantageous form of embodiment of the process the surface to be coated is curved, in particular cylindrical, or plane. By the deliberate reversal of the direction of flow of the electrolyte the form and/or

the theoretical dimension can therefore be influenced in the case of curved as well as plane surfaces. The process according to the invention is particularly advantageous in the coating of a passageway or a sack hole on whose precision of form and dimension high demands are made, such as, for example, a hole for a valve piston of a conveyance device used in a vehicle. In many cases a hole has a conical form instead of a cylindrical one after its completion, which can be compensated or eliminated by the deliberate reversal of the direction of flow of the electrolyte during the coating of the surface. Furthermore, the form of plane surfaces can be intentionally changed, in particular adjusted, with the aid of the above-described process by influencing the distribution of the thickness of the layer. Thereby plane surfaces can be produced which have a high precision of dimension.

For the realization of the objective an apparatus is also proposed which has the features of claim 6. This includes a reaction space connected to at least two connecting lines of which a first connecting line serves as inlet and a second connecting line serves as outlet for an electrolyte which can be transported by means of a feed line. The workpiece to be coated or the at least one surface is introduced into the reaction space and at least brought into contact with the electrolyte. It is also possible that the workpiece borders or forms a part of the reaction space. This is, for example, possible in the case of a workpiece with a hole to be coated. An electrode is introduced into the hole whose surface is intended to be coated. At least one anode is located in the reaction space and a cathode or the workpiece is connected to one of the two poles of the voltage source and thus forms the anode or the cathode. The apparatus is distinguished by the fact that in the path of flow of the electrolyte a change-over device, for example, a valve, is provided with whose aid the inlet and the outlet can be interchanged. With the aid

of the manually or automatically switchable change-over device a reversal of the direction of flow of the electrolyte through the reaction space at a definite point in time is possible so that a constant layer thickness or different layer thickness can be realized on the surface to be coated. Thereby the form of the surface, for example that of the hole, plate, or the like can be influenced. The inlet and the outlet are in the case of a preferred exemplary embodiment connected to the reaction space at a distance from one another in such a manner that the electrolyte preferably flows by on the entire, at least however on a large part, of the surface to be coated.

Additional advantageous forms of embodiment follow from the remaining subordinate claims.

The invention will be explained in more detail in the following with the aid of the drawings.

Shown are:

Figure 1                      a schematic sketch of an exemplary embodiment of the apparatus according to the invention,

Figures 2A to 2C            each a part of a workpiece in the area of a hole, and

Figures 3A and 3B          each a perspective view of an additional exemplary embodiment of the apparatus.

Figure 1 shows a schematic sketch of a first exemplary embodiment of an apparatus 1 for the production of wear-resistant, coated surfaces, here of a cylindrical, or essentially cylindrical, sack hole

5 introduced into a workpiece 3. A rod-like electrode 7, connected to a voltage source not represented, is inserted into the sack hole 5, said electrode having a first longitudinal section 9 of greater diameter and a second longitudinal section 11 of lesser diameter. The diameter of the electrode 7 in the area of the first longitudinal section 9 corresponds essentially to the diameter of the sack hole 5 while the diameter of the second longitudinal section 11 is smaller than that of the sack hole so that between the sack hole 5 and the electrode 7 an annular space is formed in the area of the second longitudinal section 11. In the area of the longitudinal section 11 there is introduced in the outer circumferential surface of the electrode 7 an encircling indentation in which a seal 13 is disposed with whose aid the sack hole 5 is sealed against the environment. The opening of the sack hole 5 is therefore sealed by the electrode 7, whereby a closed chamber forming a reaction space arises.

In the electrode 7 a passageway opening 15 is introduced disposed concentrically to the electrode's central longitudinal axis 14, said passageway opening being connected to a first connecting line 17 at its end opposite the base of the sack hole 5. In the area of the first longitudinal section 9 two additional passageway holes 19 disposed at a distance from the central longitudinal axis 14 are introduced into the electrode 7 which are connected to a second connecting line 21. The connecting lines 17 and 21 are connected to a change-over device which is formed here by a 4/2-way valve 23. A return line 27 leading to a container 25 for an electrolyte and a feed line 29 also connected to the container 25 are connected directly to the valve 23. Furthermore, a feed line formed here by a pump 31 is provided, said feed line sucking the electrolyte out of the container 25 and feeding it via the feed line 29, the valve 23, and one of the connecting lines 17 or 21 to the sack hole 5. The construction and the function of a

4/2-way valve 23 is known in itself so that this will not be described in more detail. The development from the standpoint of construction of the change-over device, formed here merely by way of example by a valve, can vary. What is important is that with the aid of the change-over device the direction of flow of the electrolyte in the reaction space be can be reversed.

In the following it is assumed that the workpiece 3 consists of aluminum or an aluminum alloy and that the apparatus 1 serves for the hard anodizing of the surface of the sack hole 5. In this electrolysis process the workpiece 3 serves as anode and is connected for this purpose to the positive pole of the voltage source while the electrode 7 projecting into the sack hole 5 and consisting, for example, of lead is connected to the negative pole of the voltage source and therefore serves as cathode. As the electrolyte in this process, for example, diluted sulfuric acid can be used.

In the functional position represented in Figure 1 of the four connections and valve 23 having two switch settings the electrolyte is sucked out of the container 25 by means of the pump 31 and is brought via the feed line 29, the first connecting line 17, and the passageway opening 15 introduced in the central area of the electrode 7 into the annular space bordered by the sack hole 5 and the electrode 7 and sealed against the environment. The electrolyte exiting from the passageway opening 15 directly over the base of the sack hole 5 flows along the electrode 7 or the surface of the hole in the direction of the sack hole's opening sealed by the first longitudinal section 9 of the electrode 7 and is returned via the two passageway holes 19, the second connecting line 21, and the return line 27 into the

container 25. At a precisely defined point in time the valve 23 is set manually or automatically in its second functional position. Thereby the direction of flow of the electrolyte is reversed, that is, the connecting line 17 is connected to the return line 27 and the second connecting line 21 is connected to the feed line 29. The electrolyte fed by the pump 31 from the container 25 then enters the sack hole 5 through the passageway holes 19, flows along the surface of the hole in the direction of the base of the sack hole, and is returned via the passageway opening 15 in the electrode 7, the first connecting line 17, and the return line 27 into the container 25.

With regard to the function of the electrolysis process let it be noted that for some time DC current flows through the bath, i.e., through the electrolyte, which flows through the reaction space bordered by the sack hole or the chamber closed against the environment. Thus, oxygen arises at the anode, here therefore at the surface of the hole, said oxygen reacting with the aluminum to form an adhesive oxide layer ( $\text{Al}_2\text{O}_3$ ), the so-called anodizing layer. By the appropriate choice of the point in time of the reversal of the direction of flow of the electrolyte the distribution of the thickness of the layer, i.e., the thickness of the hard anodizing surface 33 represented in Figure 1 with a dotted line, can be definitely influenced. Thereby it is possible to compensate a conicity of the sack hole 5 which, for example, is present at the completion of the sack hole 5. That is, through the at least one reversal of the direction of flow of the electrolyte at a definite point in time during the coating process it is achieved that the oxide layer has a smaller thickness at the hole's end having the smaller diameter than at the other end having the greater diameter. The conicity of the hole, which is, for example,  $6\text{ }\mu\text{m}$  at a length of the hole of

40 mm to 50 mm, can be compensated thereby so that the hole has a cylindrical form after the coating process.

From all of this it follows without further efforts for the process described that it can be used advantageously in particular wherever a high precision of form and/or dimension of the surface to be coated is required, for example, in valve piston holes in a hydraulic conveyance device, for example, a power steering pump for a vehicle.

The determination of the times for the individual flow directions, therefore the determination of the points in time of reversal of the direction of flow of the electrolyte, can be done by calculation as well as empirically by a comparison of the diameter of the hole before and after the hardening process. In the following a method for the determination of the point in time of reversal of the direction of flow or the period of time of the individual flow directions will be explained in more detail with the aid of Figures 2A to 2C, each of which shows a part of a workpiece 3 in the area of a passageway hole 35. In Figure 2A the passageway hole 35 is represented after its production but before the hard anodizing and in Figure 2C after the hard anodizing. In Figure 2B the passageway hole 35 is represented with its desired theoretical diameter and cylindrical form. To carry out the above-described process for the production of wear-resistant, coated surfaces an apparatus not represented in the Figures 2A to 2C is used whose layout is different from that described with the aid of Figure 1 with the aim that the connecting lines connected to the return line leading to the container and to the feed line connected to the pump, said



connecting lines forming the inlet and outlet for the electrolyte, are each connected to an opening of the passageway hole 35.

As can be seen from Figure 2A the passageway hole 35 has a conical form after its production, that is, the diameter of the passageway hole is different in the area of its openings. One diameter is designated by  $\varnothing_{1vor}$  and the other with  $\varnothing_{2nach}$ . After the preprocessing of the passageway hole 35 the theoretical diameters  $\varnothing_{1vor}$  and  $\varnothing_{2nach}$  are measured and from this the anodizing time is determined or calculated by means of the following equation:

$$\Delta\varnothing = \varnothing_{soll} - K(\varnothing_1 + \varnothing_2)/2,$$

where K is a parameter or a constant which can be determined empirically or by calculation.

After the coating of the passageway hole 35 the theoretical diameters  $\varnothing_{1nach}$  and  $\varnothing_{2nach}$  are determined. The times for the individual directions of flow are determined or calculated from the difference  $\varnothing_{vor} - \varnothing_{nach}$ . As represented in Figure 2C, the difference in diameter between  $\varnothing_{1nach}$  and  $\varnothing_{2nach}$  is smaller than before the coating process. The conicity is therefore substantially compensated in the case of this exemplary example. The conicity can be compensated by the above-described process at least better than is possible by the prior-art production processes designated as Dalic processes.

Figures 3A and 3B each show a perspective view of a part of an additional exemplary embodiment of the apparatus 1 in which the work piece 3 is a plate whose plane or essentially plane surface is to be

provided with an oxide layer. The tubular electrode 7 forming the cathode is held for this purpose perpendicular or essentially perpendicular and at a distance from the workpiece 3 which is located in a

reaction space, for example in a bath through which an electrolyte can flow. In the coating process the liquid electrolyte, for example sulfuric acid, is applied for a definite period of time via the passageway opening in the electrode 7 to the surface of the workpiece 3 to be coated (Figure 3A). The electrolyte is incident essentially in the middle of the plate and flows from there, as indicated with arrows 37, in the direction of the lateral edge of the workpiece 3. At a desired point in time, determined empirically or by calculation, the direction of flow of the electrolyte is reversed so that it flows from the lateral edge of the plate-like workpiece 3 into its center and is returned via the passageway opening in the electrode 7 into the container.

Through the adjustable period of time of the individual directions of flow the form of the plane surface of the workpiece 3 can be influenced and the thickness of the layer can be adjusted in the edge area as well as in the central area of the workpiece 3. Thereby unevenness on the surface to be coated can be compensated.

From all this it is clear that in connection with the present invention a closed chamber as well as a bath is understood by the term "reaction space."

In summary it remains to be determined that, with the above-described process, the thickness of the layer generated in the coating process can be influenced for curved as well as plane surfaces. By the control of the distribution of the thickness of the layer a specific effect on the form of the coated surface is furthermore possible. The development of the apparatus for the production of coated surfaces, for

example the form of the electrode forming the cathode during hard anodizing, the inlet connection and the outlet connection for the electrolyte, and the like are adapted to the form of the surface to be coated and/or the workpiece. Through the exact distribution of the thickness of the layer a reworking of the coated surface in order to obtain a desired form and/or an exact dimension, can be omitted in given cases since these parameters can be set sufficiently precisely by the precise control of the period of time of the directions of flow of the electrolyte in many cases.

### Claims

1. Process for the production of wear-resistant, coated surfaces with at least two electrodes connected to a voltage source which are mounted in, or border, a reaction space through which an electrolyte flows in which is located the surface to be coated characterized by the fact that the direction of flow of the electrolyte is reversed at least once during the coating process.
2. Process according to claim 1 characterized by the fact that the necessary precision of form of the surface to be coated is set by adherence to certain flow times.
3. Process according to claim 1 or 2 characterized by the fact that the period of time in which the electrolyte flows in a certain direction is determined as a function of the form of the surface of the workpiece before the coating process.
4. Process according to one of the preceding claims characterized by the fact that at least the surface to be coated consists of aluminum or is an aluminum alloy and that an oxide layer ( $\text{Al}_2\text{O}_3$ ) forms thereon.
5. Process according to one or more of the preceding claims characterized by the fact that the surface to be coated is curved, in particular cylindrical, or plane.

[filename]

September 14, 199[illegible]

6. Apparatus for the production of wear-resistant surfaces with a reaction space connected to at least two connecting lines where a first connecting line serves as the inlet and a second connecting line serves as the outlet for an electrolyte which can be transported with the aid of a feed line and with at least two electrodes connected to a voltage source which are mounted in the reaction space, or border it, in particular for carrying out a process according to claim 1 characterized by the fact that in the flow path of the electrolyte a change-over device (valve (23)) is provided with whose aid the inlet and the outlet can be interchanged.
7. Apparatus according to claim 6 characterized by the fact that at least the surface to be coated consists of aluminum or is an aluminum alloy and that an oxide layer ( $\text{Al}_2\text{O}_3$ ) forms thereon.
8. Apparatus according to one of the preceding claims 6 or 7 characterized by the fact that one electrode (anode) is the workpiece to be coated (3).
9. Apparatus according to one of the preceding claims 6 to 8 characterized by the fact that the surface to be coated is curved, in particular cylindrical, or plane.

**Abstract**

A process is proposed for the production of wear-resistant, coated surfaces with at least two electrodes connected to a voltage source which are mounted in, or border, a reaction space through which an electrolyte flows in which the surface to be coated is located. The process is distinguished by the fact that the direction of flow of the electrolyte is reversed at least once during the coating process.

(Figure 1)

[filename]

September 14, 199[illegible]

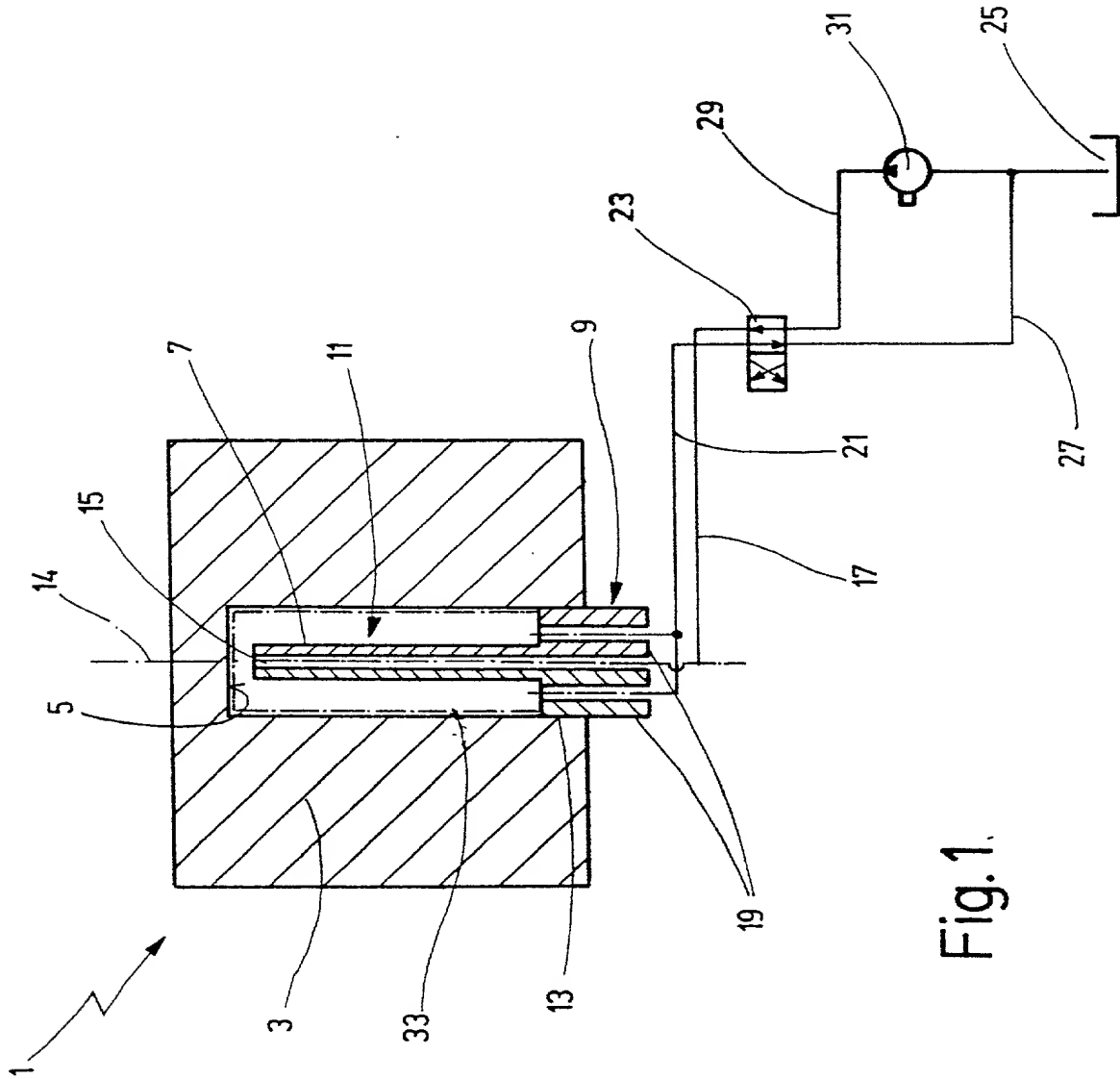


Fig. 1.

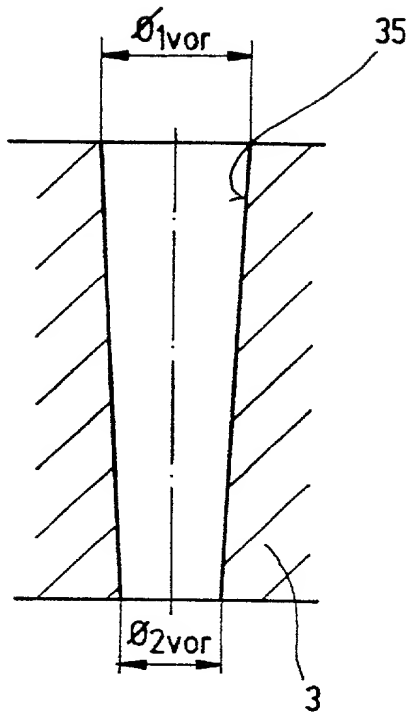


Fig. 2A

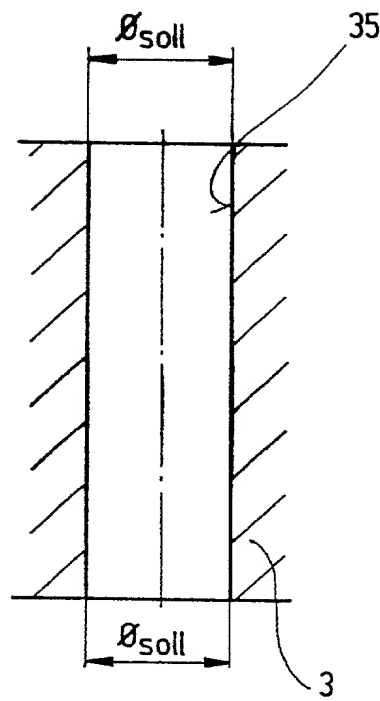


Fig. 2B

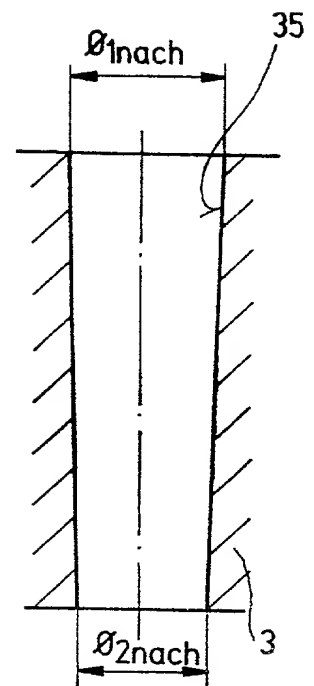


Fig. 2C

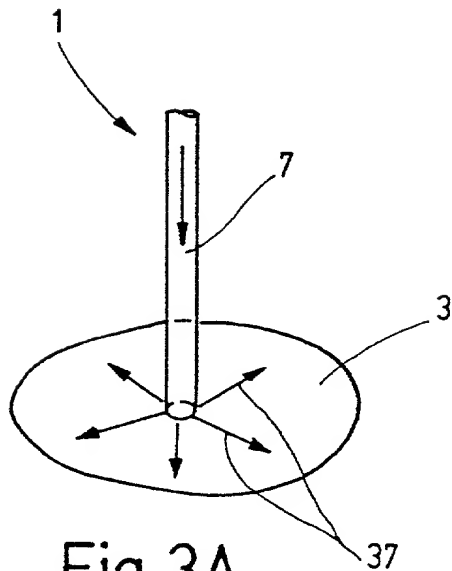


Fig. 3A

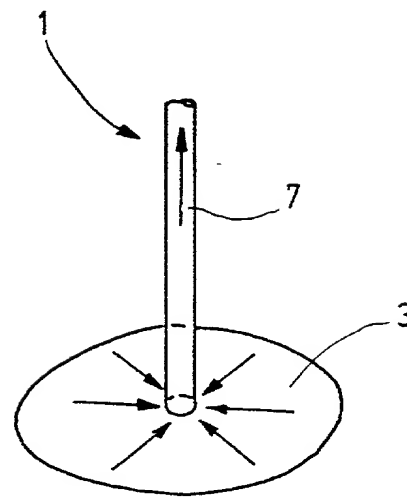


Fig. 3B



076  
23975

[illegible]

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

### Process and Apparatus for the Production of Wear-resistant Surfaces

### Process and Apparatus for the Production of Wear-resistant Surfaces

the specification of which is attached hereto unless the following box is checked:

was filed on 14 September 1998  
as United States Application Number or PCT International  
Application Number  
PCT/EP99/06800 and was amended on  
(if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56.

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(Number)	(Country)
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(Application No.)	(Filing Date)
(Aktenzeichen)	(Anmeldetag)
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(Aktenzeichen)	(Anmeldetag)

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(Application No.)	(Filing Date)
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Priority Not Claimed  
Priorität nicht beansprucht

16 September 1998 ☐  
(Day/Month/Year Filed)  
(Tag/Monat/Jahr der Anmeldung)

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(Day/Month/Year Filed)  
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(Status) (patented, pending, abandoned)  
(Status) (patentiert, schwebend, aufgegeben)

                      
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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# German Language Declaration

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(Supply similar information and signature for third and subsequent joint inventors.)

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